

Efficient Removal of Impulse Noise in Tamil Sign Language Digital Images using PSO Based Weighted Median Filter

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Abstract

Sign is the only way of communication when there is no appropriate verbal communication. Sign Language Recognition (SLR) acts as a tool to execute the conversion of sign language into text or voice. Many more techniques and algorithms have been proposed in using a variety of methods in SLR were only few considerable contributions is done in Tamil Sign Language Recognition. This paper projects a significant approach in preprocessing of real time Tamil sign language images, the primary component of SLR system. In this paper, an efficient algorithm using Particle Swarm Optimization (PSO) technique is done at the lowest level of abstraction to suppress impulse noise as well as to preserve the details of the sign. The study initially uses conventional median based filter to remove impulse noise from the distorted image but these denoised images are still suffer from blur effect which needs to be improved. The work extends its scope to use PSO algorithm to optimize non linear weights associated with the image by its median of diagonal element and maximum of horizontal and vertical element to recover the corrupted image. The centroid value of the weighted matrix of the uniform block (3X3 matrix) is the objective function of PSO. The performance of the proposed algorithm is tested and compared and the experimental results show that it removes the impulse noise effectively without any loss of information.

Keywords: Tamil Sign Language, Impulse Noise, Median Filter, Weight Matrix, Particle Swarm Optimization (PSO), Optimization.

Introduction

A study on a statistical report of physically challenged children during the past decade reveals that there is a steady increase in the number of neonates are born with defect of

hearing impairment in Tamil Nadu. A survey performed by Madras ENT Research Foundation (MERF) found that every six out of thousand children are suffered with deafest problem [10]. The growth of a child brain significantly occurs in their fundamental period of about 1-5 years. They gain more knowledge and acquire skills during this epoch. Sign language is used as a communication medium in which people can interact with others through gestures and symbols [1]. Sign language becomes an essential tool to build up linguistic skills among the deaf children. Numerous techniques and algorithms are existed for advancement of Sign Language Recognition (SLR) system. But, there is a small amount of contribution is done for the development of tamil language based SLR. The main objective of this paper is to propose significant contribution to Tamil sign language recognition system in preprocessing stage using image processing techniques in support with computational intelligence. This proposed work has been attempted with Tamil letters like 12 uyir and 1 Aayutha Ezhuthu and each represents the static images of the palm side of right hand. Figure 1 depicts the generated TSL dataset. The organization of the paper is follows as. Section 2 gives the information on digital images corrupted with impulse noise and the need for preprocessing. Section 3 explains the implementation of conventional median filters in real time TSL datasets. Section 4 explains the proposed optimized filter using PSO. Section 5 depicts the evaluation assessments of the experimental results. Section 6 concludes the findings and discusses the extension scope of the research work in TSLR.



Fig. 1. Manually Generated Tamil Sign Language Dataset (12 Uyir and 1 Aayutha Ezhuthukkal)

Preprocessing

Acquisition of digital image contains impulse noise which can be added due to various circumstances involves fault in electronic devices, poor weather conditions, human mistakes etc., [3]. This kind of noise could be eliminated to improve the quality of the image. Indeed, removal of impulse noise in digital image is a crucial task in the preprocessing phase. Several algorithms are existed for noise removal as well as without affect the information contained in the digital image [8]. A various kinds of median filter techniques have been introduced for image denoising [2]. But, the accuracy of the result still needs to be improved. It can be achieved by optimizing the weights generated in median filter and implemented across the image in a uniform manner.

A. Impulse Noise

The probability of occurrence of impulse noise in digital image can be represented as follows:

$$X(k) = \begin{cases} n(k) \text{ with probability } p \\ f(k) \text{ with probability } 1 - p \end{cases} \quad (1)$$

where n (k) indicate the image which contains noise with the ratio of p and f (k) designate the ratio of pixels of an image without noise in it. The uniformly distributed impulse noise values lies within the range of [0, 255] at probability p.

Implementation of Conventional Median Filters

The objective of this research work is to apply particle swarm optimization (PSO) algorithm to optimize the weights generated in median filter in order to suppress the noise level present in the TSL dataset. Experiments are conducted by using four algorithms such as median filter, adaptive median filter, DB median filter, PSO based weighted filter and its performance of the result have been examined.

A. Image denosing using median filter

Median filtering technique is used to reduce impulsive noise while preserve the edges around the image. It selects centric value and rest of the pixels is replaced with a median value. The demerits observed from the technique are that it may loss of finer details in the image [5]. It is represented by following mathematical equation (2)

$$\Omega_i^w = \begin{cases} j = \frac{j_1+j_2}{2} - \frac{w-1}{2} \leq j_1 \leq i_1 + (w-1)/2, \\ I_2 - \frac{w-1}{2} \leq j_2 \leq i_2 + (w-1)/2 \end{cases} \quad (2)$$

B. Image denosing using adaptive median filter

The adaptive median filter is defined as assignment of weight to the pixel values based on the level of noise content present in the image. It allocates small filter size for low noise level

and large filter size for high noise level of the pixel location. The level of operation defined as the following equation [5]

$$\text{Level: } Level1 = Z_{median} - Z_{minimum} \\ Level2 = Z_{median} - Z_{maximum}$$

If Level1>0 AND Level2<0, then process level H else the size of the window is increased by 2
 If window size>=S_{max} then repeat Level else print the output of Z_{xy}

$$\text{Level H: } H1 = Z_{medianxy} - Z_{minimum} \\ H2 = Z_{medianxy} - Z_{maximum}$$

If H1>0 AND H2<0, output Z_{xy} else output Z_{median}
 The maximum limit of the window size is calculated which is chosen as the median value. But this technique still needs to be improved for succumb quality of results in images which contain edges.

C. Image denosing using decision based median filter

Decision based median filter is defined as the process of removing noise values with the most appropriate reliable value selected by noise detector. This technique helps to preserve the high quality conformity of the image. The neighbourhood value of the noisy pixel is chosen as the reliable value. Let X_{ij} be the pixel value, X_{maximum}, X_{minimum}, and X_{median} be the maximum, minimum and median value of the pixel. If X_{minimum}<X_{ij}<X_{maximum} then the pixel value is not corrupted and therefore the pixel value is retained. If X_{ij} is corrupted noise then it checks for median value whether it is impulse noise or not. If X_{minimum}<X_{median}<X_{maximum} or 0<X_{median}<255, then median is not taken as impulse noise value. Therefore, the centroid value is substituted with the median value of the window to get the filtered denoising output of the image [6].

D. Image denosing using weighted median filter

Weighted median filter is defined as the process of estimate the sum of the weights associated with an image of window size up to 2k+1 [9]. It is an efficient method to suppress the noise as well as preserve the fidelity of an image. The Weighted Median filter can be distinct in two different forms. The most commonly used one assumes positive integer with odd sum.

Definition 1: For the discrete-time continuous –valued input vector I.

$$I = (I_1, I_2, \dots, I_N)$$

The output Y of the WM filter of span N associated with the integer weights w = (w₁, w₂, …, w_N) is given by equation (3.4.1)

$$Y = \text{MEDIAN} \{ w_1|I_1, w_2|I_2, \dots, w_N|I_N \} \quad (3)$$

where MEDIAN { . } refer to the median operation and | symbolize duplication

Definition 2: This kind of weighted median filter technique allows set of non negative decimal weights w applied to the discrete value of image I to calculate the average of sample I_i. It is denoted by the following equation (4).

$$\varphi(\beta) = \sum_{i=1}^N w_i |I_i - \beta| \quad (4)$$

β is the sample of I_i , $\varphi(\cdot)$ is a linear and convex value while $w_i \geq 0$ for all i . Figure 2 portray the subjective assessment of the traditional filters on TSL datasets.

Tamil vowels	அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	ஐ	ஓ	ஔ	ஓள	ஃ
Original image													
Median filter													
Adaptive filter													
DB median filter													
Weighted filter													

Fig. 2. Visual Assessment of the Filters (a) Tamil Vowels (b) Original Image (c) Median Filter (d) Adaptive median filter (e) Decision based median filter (f) Weighted Median filter

Tamil vowels	அ	ஆ	இ	ஈ	உ	ஊ	எ	ஏ	ஐ	ஓ	ஔ	ஓள	ஃ
Original image													
Rotated ellipse2													
schwefel													
sphere													

Fig. 3. Visual Assessment of Proposed OWMF using PSO with three different objective functions

Proposed Noise Removal Algorithm using PSO

The proposed PSO optimization based weighted median filtering technique optimize the weights given in the weighted matrix in order to retrieve the high quality filtered image using standard benchmark functions. Particle Swarm Optimization [PSO] is a swarm intelligence algorithm used for optimizing the distributed weights W_{ij} , randomly generated in a weighted median filter technique. The flowchart (figure 4) below depicts the skeleton of the proposed work.

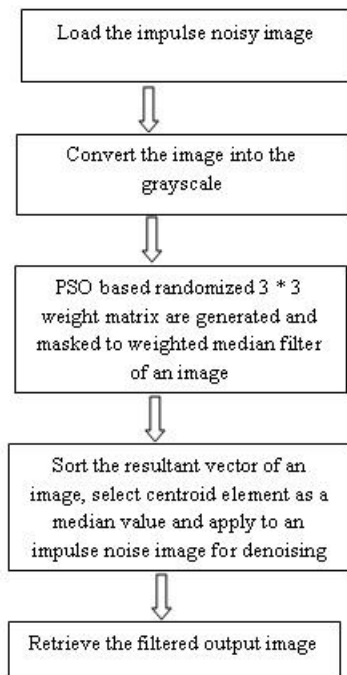


Fig. 4. Proposed Optimized Weighted Median Filter using PSO

Procedure

- Step 1:** A sign language input image $I(u,v)$ has been chosen for removing the impulse noise contains in it.
- Step 2:** A population of weighted particles says p , of size m ($0 < m <= 1$) are generated and initialized with random position x_p and velocity v_p .
- Step 3:** For each particle, evaluate the objective (fitness) function using multiple benchmark functions such as Rotated Ellipse2, Schwefel and Sphere.
- Step 4:** Based on the evaluation of objective function (maxima or minima), an individual best (Cognitive) p_{best} is chosen for each iteration.
- Step 5:** Suppose the current particle p_i value is better than previous value $p_{besti-1}$, set the current particle p_i as the p_{best} value. Otherwise set previous value $p_{besti-1}$ as individual best (Cognitive) p_{best} .
- Step 6:** Particles in the neighborhood with the best success so far g_{best} are identified and assigned to the index variable g .
- Step 7:** Update the velocity and position of a particle at time t using the following equations:

$$V_{ij}^{(t+1)} = \omega * V_{ij} + (c_1 * r_1 * (P_{best} - x_p) + (c_2 * r_2 * (P_g - x_p)) \quad (5)$$

$$X_{ij}^{(t+1)} = X_{ij} + V_{ij}^{(t+1)} \quad (6)$$

Where

- V_{ij} = velocity of j^{th} particle of i^{th} iteration
- X_{ij} = Position of j^{th} particle of i^{th} iteration
- ω = inertia weight acts an external force in which a particle moves in the problem space; set ($\omega = 0.4$)
- c_1, c_2 = acceleration coefficients. It enables the convergence of P_{best} and G_{best} particles in an stability condition; ($c_1=c_2=2.0$)
- r_1, r_2 = random numbers lies between 0 and 1
- P_{best} = Personal (individual) particle best p
- G_{best} = Neighborhood (social) particle best g

- Step 8:** Repeat the steps 3 to 7 either for maximum number of iterations or criteria (determination) is to be met.
- Step 9:** PSO based weight values are randomly generated for a weight matrix W_{ij} and assigned to individual pixels of an image
- Step 10:** The resultant vector of an image are sorted, then a centroid element in a matrix are chosen as a median value which applies to an original image for denoising process
- Step 11:** The filtered output image are obtained and used for further analysis.

Results and Discussions

The results are generated by using MATLAB and JAVA. The methodology is experimented with TSL Datasets with limitation of single handed signs and black background images. Digital images are first converted to gray scale images and then filtered by standard non linear filters such as median, adaptive, decision based and weighted median filter. These filters are tested and compared to find out the best impulse eliminator and therefore optimize the Weighted Median Filter using PSO. The performance metrics used for objective evaluation are Peak signal to Noise Ratio (PSNR), Mean Square Error (MSE), Mean Absolute Error (MAE) and Correlation.

Peak signal-to-noise ratio (PSNR) is defined as the quantitative assessment between original pixel value and reinstate noise value of the image. It is measured by using the equation (7):

$$PSNR = 10 \log_{10}(255^2 / MSE) \quad (7)$$

TABLE.1. Objective evaluation of the adopted filtering methods using standard image quality metrics

Alphabet	Median filter				Adaptive filter				Db median filter				Weighted median			
	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL
अ	42.11	1.47	0.73	0.9997	48.85	0.92	0.35	0.9999	46.51	1.20	0.19	0.9998	65.15	0.14	0.09	0.9931
क	45.78	1.30	0.66	0.9997	49.09	0.89	0.35	0.9998	47.39	1.08	0.18	0.9999	62.79	0.08	0.99	0.9931
इ	42.70	1.86	0.88	0.9997	46.77	1.16	0.41	0.9998	46.90	1.15	0.19	0.9997	64.86	0.08	0.02	0.9933
फ	47.38	1.08	0.50	0.9998	51.87	0.65	0.25	0.9999	48.73	0.93	0.14	0.9999	65.46	0.13	0.09	0.9952

உ	42.61	1.88	0.80	0.9995	46.85	1.16	0.41	0.9998	46.18	1.25	0.19	0.9998	65.33	0.14	0.09	0.9937
ஊ	44.71	1.48	0.75	0.9996	48.79	0.93	0.34	0.9998	48.57	0.95	0.17	0.9998	65.53	0.13	0.10	0.9941
எ	46.36	1.22	0.58	0.9998	50.60	0.75	0.27	0.9999	48.21	0.99	0.16	0.9999	64.58	0.15	0.10	0.9952
ஏ	43.44	1.71	0.82	0.9996	47.28	1.10	0.37	0.9998	45.31	1.38	0.21	0.9997	64.44	0.15	0.11	0.9929
ஐ	46.69	1.18	0.61	0.9998	50.41	0.76	0.32	0.9999	47.58	1.06	0.17	0.9998	64.86	0.14	0.10	0.9946
ஓ	42.68	1.87	0.81	0.9994	47.05	1.13	0.38	0.9998	46.58	1.19	0.18	0.9997	66.04	0.12	0.09	0.9927
ஔ	47.47	1.07	0.53	0.9998	52.18	0.62	0.23	0.9999	49.49	0.85	0.15	0.9999	64.22	0.15	0.12	0.9942
ஓள	46.27	1.23	0.59	0.9997	50.42	0.76	0.29	0.9999	47.98	1.01	0.15	0.9998	65.36	0.13	0.09	0.9935
∴	42.19	1.98	1.09	0.9993	46.05	1.26	0.46	0.9997	46.09	1.26	0.23	0.9997	63.95	0.16	0.13	0.9925

Mean Square error (MSE) is distinct as the average estimation of restored noisy pixels in the original image. MSE is calculated using equation (8):

$$MSE = \frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N [g(i,j) - f(i,j)]^2 \quad (8)$$

Mean Absolute Error (MAE) is average of absolute difference between the reference signal and test image. MAE is calculated using equation (9) [7]

$$MAE(I, \hat{I}) = \frac{1}{M \times N} \sum_{i=1}^M \sum_{j=1}^N |I_{ij} - \hat{I}_{ij}| \quad (9)$$

TABLE.2. Objective evaluation of the OWMF using PSO based on three OF (Min)

Alphabet	Rotated ellipse2 g best(min)				Schwefel g best(min)				Sphere g best(min)			
	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL
அ	65.00	0.14	0.10	0.996	66.03	0.13	0.09	0.9971	61.27	0.14	0.10	0.996
ஆ	64.90	0.14	0.11	0.997	65.95	0.13	0.09	0.9958	61.19	0.14	0.11	0.9970
இ	64.74	0.14	0.11	0.994	65.80	0.13	0.09	0.9967	61.04	0.14	0.11	0.995
ஈ	65.55	0.13	0.09	0.997	66.56	0.11	0.08	0.9978	61.78	0.20	0.14	0.997
உ	65.09	0.14	0.10	0.995	66.12	0.12	0.09	0.9966	61.38	0.21	0.15	0.996
ஊ	65.55	0.13	0.10	0.996	66.52	0.12	0.09	0.9959	61.79	0.20	0.16	0.995
எ	64.57	0.15	0.11	0.997	65.55	0.13	0.09	0.9971	60.80	0.23	0.17	0.997
ஏ	64.35	0.15	0.12	0.994	65.40	0.13	0.10	0.9955	60.64	0.23	0.17	0.994
ஐ	65.00	0.14	0.10	0.996	66.01	0.12	0.09	0.9970	61.24	0.22	0.15	0.997
ஓ	65.74	0.14	0.10	0.996	66.73	0.11	0.08	0.9955	62.03	0.20	0.14	0.995
ஔ	64.39	0.14	0.11	0.997	65.34	0.13	0.10	0.9966	60.60	0.23	0.18	0.996
ஓள	65.52	0.14	0.11	0.994	66.49	0.12	0.08	0.9958	61.77	0.20	0.15	0.996
∴	64.01	0.13	0.09	0.997	64.98	0.14	0.11	0.9930	60.26	0.24	0.16	0.992

Correlation is the closeness between two digital images can also be quantified in terms of similarity between two images and is given by the equation (10)

$$NK = \frac{\sum_{i=1}^M \sum_{j=1}^N (x(i,j)xy(i,j))}{\sum_{i=1}^M \sum_{j=1}^N (x(i,j))^2} \quad (10)$$

Table 1, 2 and 3 gives the analysis of the methods in terms of objective evaluation metrics. It is essential to increase the window size to increase the performance of the filters. On experiment it is found that the increase of window size has lead to blurring effect in images. It is also observed that, techniques lowered its performance when the noise density is

high. When compared to the conventional filtering methods, the proposed PSO optimized weighted median filter ultimately reduces the blurring effect of the image. Results are taken with three standard benchmark functions such as Rotated Ellipse2, Sphere and Schwefel for 100 to 500 parameter range. From the study of the results it observes that PSNR and MSE metrics for PSO optimized weighted median filter give better results than conventional median filter techniques. From the experiments conducted on TSL datasets, it is infer that the proposed optimized weighted median filter (OWMF) using PSO give better results for various standard metrics than existing traditional algorithms.

TABLE. 3. Objective evaluation of the OWMF using PSO based on three OF (Max)

Alphabet	Rotated ellipse2 g best(max)				Schwefel g best(max)				Sphere g best(max)			
	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL	PSNR	MSE	MAE	CORL
அ	67.93	0.10	0.09	0.994	63.87	0.16	0.12	0.992	63.76	0.10	0.07	0.993
ஆ	67.86	0.10	0.09	0.992	63.77	0.16	0.12	0.993	63.67	0.10	0.99	0.994
இ	67.71	0.11	0.09	0.994	63.62	0.16	0.12	0.994	63.52	0.11	0.07	0.995
ஈ	68.52	0.09	0.08	0.995	64.36	0.15	0.11	0.997	64.27	0.15	0.11	0.997
உ	67.71	0.10	0.09	0.993	63.98	0.16	0.11	0.995	63.86	0.16	0.12	0.996
ஊ	68.53	0.09	0.09	0.993	64.39	0.15	0.12	0.995	64.27	0.15	0.12	0.996
எ	67.57	0.10	0.09	0.995	63.41	0.17	0.13	0.996	63.30	0.17	0.12	0.997
ஏ	67.27	0.11	0.10	0.992	63.22	0.17	0.13	0.994	63.12	0.17	0.13	0.994
ஐ	68.03	0.10	0.09	0.995	63.22	0.17	0.13	0.994	63.73	0.16	0.12	0.997
ஓ	68.58	0.09	0.08	0.992	63.83	0.16	0.12	0.996	64.49	0.15	0.11	0.995
ஔ	67.40	0.10	0.10	0.994	64.63	0.14	0.15	0.994	63.10	0.17	0.14	0.997
ஔ௭	68.52	0.09	0.08	0.994	64.33	0.15	0.11	0.995	64.25	0.15	0.11	0.996
∴	66.96	0.11	0.99	0.990	62.83	0.18	0.13	0.992	62.74	0.18	0.15	0.993

Conclusions

Digital images of Tamil sign language are always corrupted with impulse noise. In this research work, different types of median filtering techniques have been analyzed and the proposed PSO based OWMF method has been examined with standard benchmark functions involves sphere, rotated ellipse2 and schwefel. The primary benefit of the proposed work is that the selection of weights in the median filter technique is considered as non-linear optimization problem. Particle Swarm Optimization (PSO) algorithm is implemented to optimise the weights which are generated in the weighted matrix. Then, the process of convolution of weights associated with the pixels filters impulse noise without loss of lines and edges present in the original image. Experimental results validate its potential detection of corrupted noise along with preserving the fine details of the image. The highest PSNR and lowest MAE values across a wide range of noise densities including the visual clarity reveals the same. Therefore an extensive loss of image is reduced without reducing the image fine details. In future, the work can be extended to segmentation stage for TSL recognition and also to attempt with background independent instead of following uniform background.

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